Chemistry 11 Review

Dissolving Chemicals in Water

1.) Write the equation for the equilibrium reaction existing in each of the following saturated aqueous solutions.

a.) K_3PO_4 b.) NH_4Cl c.) $Al(NO_3)_3$

a.) Answer – $K_3PO_{4\,(s)} \leftrightarrow 3\ K^+_{(aq)} + PO_4^{-3}{}_{(aq)}$

b.) Answer – $NH_4Cl_{(s)} \leftrightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$

c.) Answer – $Al(NO_3)_{3\,(s)} \leftrightarrow Al^{+3}{}_{(aq)} + 3\ NO_3^-{}_{(aq)}$

2.) Write the **crystallization reaction** involving $MgBr_{2\,(s)}$. Answer – $Mg^{+2}{}_{(aq)} + 2\ Br^-{}_{(aq)} \rightarrow MgBr_{2\,(s)}$

3.) Write the **dissolving reaction** involving $C_6H_{12}O_{6\,(s)}$. Answer – $C_6H_{12}O_{6\,(s)} \rightarrow C_6H_{12}O_{6\,(aq)}$

4.) A container containing a saturated solution of NaCl is carefully picked up and $100\ mL$ of the solution is poured into a second container. If you are careful not to transfer any of the crystals will the second containers salt solution be saturated?

Answer – No. There must be an equilibrium established for a truly saturated solution. No solids (table salt) means there is no chemical on both sides of the equilibrium so there is no equilibrium.

5.) A student half filled a $100\ mL$ container with water and added a few grams of NaCl crystals. Seeing the crystals sink and settle on the bottom, the student said the solution must be saturated. Was the student correct? Why?

Answer – No. There is time needed for the dissociation reaction to occur. This could be anywhere from a few minutes to days.

6.) Aluminium fluoride has a solubility of $5.59\ g/L$ at $20°C$. Express this solubility in $\frac{mol}{L}\ or\ M$.

Answer – $\frac{5.59\ g}{L} \times \frac{1\ mol}{83.8\ g} =$ $= 0.06670\ M$ $= 0.0667\ M\ AlBr_3$

7.) Lead (II) chloride has a solubility of $0.99 \frac{g}{100.0} mL$ at $20°C$. Calculate the molar solubility.

Answer – $\frac{0.99\ g}{100\ mL} \times \frac{1\ mol}{278.1\ g} \times \frac{1000\ mL}{1\ L} =$ $= 0.035599\ M$ $= 0.036\ M\ PbCl_2$

8.) The molar solubility of Ag_2CO_3 is $1.2 \times 10^{-4}\ M$ at $25°C$. Express this value in $\frac{g}{100.0\ mL}$.

Answer – $\frac{1.2\times10^{-4}\ mol}{1\ L} \times \frac{275.75\ g}{1\ mol} \times 0.100\ L =$ $= 0.003309\ g\ (per\ 100\ mL)$ $= \frac{0.0033 g}{100.0\ mL}\ Ag_2CO_3$

9.) Manganese (II) chloride has a molar solubility of $5.75\ M$ at $0°C$. If $125\ mL$ of the saturated solution is evaporated to dryness, what mass of the chemical will be left?

Answer – $\frac{5.75\ mol}{1\ L} \times \frac{125.84\ g}{1\ mol} \times 0.125\ L = \quad = 90.4475\ g \quad = 90.4\ g\ MnCl_2$

10.) Calculate the concentration of each ion in each of the following solutions.

a.) $0.25\ M\ FeCl_3$ Answer – $FeCl_{3\ (s)} \leftrightarrow Fe^{+3}{}_{(aq)} + 3\ Cl^-{}_{(aq)}$ $1:1:3\ ratio$

$0.25\ M\ Fe^{+3}$ and $0.75\ M\ Cl^-$

b.) $1.5 \times 10^{-3} M\ Al_2(SO_4)_3$ Answer – $Al_2(SO_4)_{3\ (s)} \leftrightarrow 2\ Al^{+3}{}_{(aq)} + 3\ SO_4{}^{-2}{}_{(aq)}$ $1:2:3\ ratio$

$3.0 \times 10^{-3}\ M\ Al^{+3}$ and $4.5 \times 10^{-3}\ M\ SO_4{}^{-2}$

c.) $12.0\ g\ (NH_4)_2CO_3$ in $2.50\ L$ Answer – $12.0\ g \times \frac{1\ mol}{96.11\ g} \times \frac{1}{2.50\ L} = 0.0499427\ M$

$(NH_4)_2CO_{3\ (s)} \leftrightarrow 2\ NH_4{}^+{}_{(aq)} + CO_3{}^{-2}{}_{(aq)}$ $1:2:1\ ratio$ $0.0.100\ M\ NH_4{}^+$ and $0.0499\ M\ CO_3{}^{-2}$

d.) $0.41\ g\ Ca(OH)_2$ in $500\ mL$ of aqueous solution Answer – $0.41\ g \times \frac{1\ mol}{74.10\ g} \times \frac{1}{0.500\ L} = 0.011066\ M$

$Ca(OH)_2 \leftrightarrow Ca^{+2} + 2\ OH^-$ $1:1:2\ ratio$ $0.01\ M\ Ca^{+2}$ and $0.02\ M\ OH^-$

11.) a.) Write an equation showing the equilibrium in a saturated solution of lead (II) bromide.

Answer – $PbBr_{2\ (aq)} \leftrightarrow Pb^{+2}{}_{(aq)} + 2\ Br^-{}_{(aq)}$

b.) The solubility of $PbBr_2$ is $0.844 \frac{g}{100\ mL}$. What is its molar solubility?

Answer – $\frac{0.844\ g}{100\ mL} \times \frac{1000\ mL}{1\ L} \times \frac{1\ mol}{367.0\ g} = 0.0229973\ M \quad = 0.230\ M$

c.) Calculate the concentration of $Pb^{+2}{}_{(aq)}$ and $Br^-{}_{(aq)}$ in a saturated solution of $PbBr_2$.

Answer – $PbBr_{2\ (aq)} \leftrightarrow Pb^{+2}{}_{(aq)} + 2\ Br^-{}_{(aq)}$ 1:1:2

$0.230\ M \quad 0.230\ M \quad 0.460\ M$

12.) Calculate the concentration of each of the following ions present when

a.) $25.0\ mL$ of water is added to $20.0\ mL$ of $0.35\ M\ Fe^{+3}$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $(0.35) \times (0.0200) = (C_{dil}) \times (0.0450)$

$[Fe^{+3}]_{dil} = 0.035\ M \times \frac{0.0200\ L}{(0.020+0.025)\ L} = 0.16\ M$

b.) $50.0\ mL$ of $0.25\ M\ Ag^+$ is mixed with $100.0\ mL$ of $0.10\ M\ NO_3{}^-$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $(0.25) \times (0.0500) = (C_{dil}) \times (0.150)$

$[Ag^+]_{dil} = 0.83\ M$

$C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $(0.10) \times (0.100) = (C_{dil}) \times (0.150)$

$[NO_3{}^-]_{dil} = 0.67\ M$

c.) $55.0\ mL$ of $0.185\ M\ MgCl_2$ is mixed with $25.0\ mL$ of $4.8 \times 10^{-2}\ M\ CaBr_2$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $(0.185)(0.0550) = (C_{dil}) \times (0.0750)$

$[MgCl_2]_{dil} = 0.136\ M$

$C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $(0.048) \times (0.0250) = (C_{dil}) \times (0.0750)$

$[CaBr_2]_{dil} = 0.016\ M$

$MgCl_2 \leftrightarrow Mg^{+2} + 2\,Cl^-$ $\qquad$ $CaBr_2 \leftrightarrow Ca^{+2} + 2\,Br^-$

$0.136\ M \quad 0.136\ M \quad 0.272\ M$ $\qquad$ $0.016\ M \quad 0.016\ M \quad 0.032\ M$

d.) $95.0\ mL$ of $8.65 \times 10^{-4} M\ Al(NO_3)_3$ is mixed with $15.0\ mL$ of $7.50 \times 10^{-6}\ M\ Ag_2SO_4$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(8.65 \times 10^{-4})(0.0950) = (C_{dil}) \times (0.110)$

$[Al(NO_3)_3]_{dil} = 7.47 \times 10^{-4}\ M$

$C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(7.50 \times 10^{-6}) \times (0.0150) = (C_{dil}) \times (0.110)$

$[Ag_2SO_4]_{dil} = 1.02 \times 10^{-6}\ M$

$Al(NO_3)_3 \leftrightarrow Al^{+3} + 3\,NO_3{}^-$

$7.47 \times 10^{-4}\ M \quad 7.47 \times 10^{-4}\ M \quad 2.24 \times 10^{-3}\ M$

$Ag_2SO_4 \leftrightarrow 2\,Ag^{+2} + SO_4{}^{-2}$

$1.02 \times 10^{-6}\ M \quad 2.05 \times 10^{-6}\ M \quad 1.02 \times 10^{-6}\ M$

e.) $25.0\ mL$ of $0.360\ M\ NH_4Br$ is mixed with $75.0\ mL$ of $0.160\ M\ (NH_4)_2SO_4$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(0.360)(0.0250) = (C_{dil}) \times (0.100)$

$[NH_4Br]_{dil} = 0.0900\ M$

$C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(0.160) \times (0.0750) = (C_{dil}) \times (0.100)$

$[(NH_4)_2SO_4]_{dil} = 0.120\ M$

$NH_4Br \leftrightarrow NH_4{}^+ + Br^-$ $\qquad$ $(NH_4)_2SO_4 \leftrightarrow 2\,NH_4{}^+ + SO_4{}^{-2}$

$0.0900\ M \quad 0.0900\ M \quad 0.0900\ M$ $\qquad$ $0.120\ M \quad 0.240\ M \quad 0.120\ M$

$[NH_4{}^+] = 0.0900 + 0.240$ $\qquad$ $[NH_4{}^+] = 0.330\ M$

f.) $10.0\ mL$ of $0.100\ M\ Ba(NO_3)_2$ is mixed with $40.0\ mL$ of $0.300\ M\ AgNO_3$.

Answer – $C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(0.100)(0.0100) = (C_{dil}) \times (0.0500)$

$[Ba(NO_3)_2]_{dil} = 0.0200\ M$

$C_{conc} \times V_{conc} = C_{dil} \times V_{dil}$ $\qquad$ $(0.300) \times (0.0400) = (C_{dil}) \times (0.0500)$

$[AgNO_3]_{dil} = 0.240M$

$AgNO_3 \leftrightarrow Ag^+ + NO_3{}^-$ $\qquad$ $Ba(NO_3)_2 \leftrightarrow Ba^+ + 2\,NO_3{}^-$

$0.240\ M \quad 0.240\ M \quad 0.240\ M$ $\qquad$ $0.0200\ M \quad 0.0200\ M \quad 0.0400\ M$

$[NH_4{}^+] = 0.0400 + 0.240$ $\qquad$ $[NH_4{}^+] = 0.330\ M$

13.) For each of the following combinations of equal volumes of $0.20\ M$ aqueous solutions,

i.) Identify possible products by formula. red

ii.) State which (if any) product has a low solubility. (underlined)

iii.) If there **is** a precipitate write the formula equation, total ionic equation, and net ionic equation for the reaction.

a.) $MgS_{(aq)} + Sr(OH)_{2\,(aq)} \leftrightarrow \underline{Mg(OH)_{2\,(s)}} + SrS$

$Mg^{+2}{}_{(aq)} + S^{-2}{}_{(aq)} + Sr^{+2}{}_{(aq)} + 2\,OH^-{}_{(aq)} \rightarrow Mg(OH)_{2\,(s)} + Sr^{+2}{}_{(aq)} + S^{-2}{}_{(aq)}$

$Mg^{+2}{}_{(aq)} + 2\,OH^-{}_{(aq)} \leftrightarrow Mg(OH)_{2\,(s)}$

b.) $CuBr_{2\,(aq)} + Pb(NO_3)_{2\,(aq)} \leftrightarrow \underline{PbBr_{2\,(s)}} + Cu(NO_3)_{2\,(aq)}$

$Cu^{+2}_{(aq)}$ + 2 $Br^{-2}_{(aq)}$ + $Pb^{+2}_{(aq)}$ + 2 $NO_3^-{}_{(aq)}$ → $PbBr_{2\,(s)}$ + $Cu^{+2}_{(aq)}$ + 2 $NO_3^-{}_{(aq)}$

$Pb^{+2}_{(aq)}$ + 2 $Br^-_{(aq)}$ ↔ $PbBr_{2\,(s)}$

c.) K_3PO_4 + $CuCl_2$ ↔ $\underline{Cu_3(PO_4)_{2\,(s)}}$ + $KCl_{(aq)}$

3 $K^+_{(aq)}$ + $PO_4^{-3}{}_{(aq)}$ + $Cu^{+2}_{(aq)}$ + 2 $Cl^-_{(aq)}$ → $Cu_3(PO_4)_{2\,(s)}$ + $K^+_{(aq)}$ + $Cl^-_{(aq)}$

3 $Cu^{+2}_{(aq)}$ + 2 $PO_4^{-3}{}_{(aq)}$ ↔ $Cu_3(PO_4)_{2\,(s)}$

d.) $(NH_4)_2SO_3$ + $Al_2(SO_4)_3$ ↔ $\underline{Al_2(SO_3)_{3\,(s)}}$ + $(NH_4)_2SO_{4\,(aq)}$

2 $NH_4^+{}_{(aq)}$ + $SO_3^{-2}{}_{(aq)}$ + 2 $Al^{+3}_{(aq)}$ + 3 $SO_4^{-2}{}_{(aq)}$ → $Al_2(SO_3)_{3\,(s)}$ + 2 $NH_4^+{}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$

2 $Al^{+3}_{(aq)}$ + 3 $SO_3^{-2}{}_{(aq)}$ ↔ $Al_2(SO_3)_{3\,(s)}$

e.) silver nitrate and sodium phosphate $AgNO_{3\,(aq)}$ + $Na_3PO_{4\,(aq)}$ ↔ $\underline{Ag_3PO_{4\,(s)}}$ + $NaNO_{3\,(aq)}$

$Ag^+_{(aq)}$ + $NO_3^-{}_{(aq)}$ + 3 $Na^+_{(aq)}$ + $PO_4^{-3}{}_{(aq)}$ → $Ag_3PO_{4\,(s)}$ + $Na^+_{(aq)}$ + $NO_3^-{}_{(aq)}$

3 $Ag^+_{(aq)}$ + $PO_4^{-3}{}_{(aq)}$ ↔ $Ag_3PO_{4\,(s)}$

f.) zinc sulphate and iron (II) chloride $ZnSO_{4\,(aq)}$ + $FeCl_{2\,(aq)}$ ↔ $ZnCl_{2\,(aq)}$ + $FeSO_{4\,(aq)}$

$Zn^{+2}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$ + $Fe^{+2}_{(aq)}$ + 2 $Cl^-_{(aq)}$ → Zn^{+2} + $SO_4^{+2}{}_{(aq)}$ + $Fe^{+2}_{(aq)}$ + 2 $Cl^-_{(aq)}$

g.) beryllium sulphate and ammonium carbonate $BeSO_{4\,(aq)}$ + $(NH_4)_2CO_{3\,(aq)}$ ↔ $\underline{BeCO_{3\,(s)}}$ + $(NH_4)_2SO_{4\,(aq)}$

$Be^{+2}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$ + 2 $NH_4^+{}_{(aq)}$ + $CO_3^{-2}{}_{(aq)}$ → $BeCO_{3\,(s)}$ + 2 $NH_4^+{}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$

$Be^{+2}_{(aq)}$ + $CO_3^{-2}{}_{(aq)}$ ↔ $BeCO_{3\,(s)}$

h.) magnesium sulphate and strontium hydroxide $MgSO_{4\,(aq)}$ + $Sr(OH)_{2\,(aq)}$ ↔ $\underline{Mg(OH)_{2\,(s)}}$ + $\underline{SrSO_{4\,(s)}}$

$Mg^{+2}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$ + $Sr^{+2}_{(aq)}$ + 2 $OH^-_{(aq)}$ → $SrSO_{4\,(s)}$ + $Mg(OH)_{2\,(s)}$

$Mg^{+2}_{(aq)}$ + 2 $OH^-_{(aq)}$ ↔ $Mg(OH)_{2\,(s)}$

$Sr^{+2}_{(aq)}$ + $SO_4^{-2}{}_{(aq)}$ ↔ $SrSO_{4\,(s)}$

14.) Solubility can be used in the field of **Qualitative Analysis.** This field of chemistry involves the use of experimental procedures to determine which elements or ions are present in a substance.

A solution contains Al^{+3} and Ag^+. What **compounds** could be added, and in what order, to separate these ions?

Answer – 1.) Add chloride, bromide, iodine, or sulphate ions to solution. All of these will precipitate out the silver ions.

2.) Add sulphide, hydroxide, phosphate, carbonate, or sulphite ions and aluminium will precipitate out.

15.) A solution contains Fe^{+3}, Ca^{+2}, Ag^+, and Be^{+2}. What **compounds** could be added, and in what order, to separate out these ions?

Answer – 1.) Add NaCl or KBr or NaI ppt Ag^+. 2.) Add $K_2SO_4^{-2}$ ppt Ca^{+2}.

3.) Add $(NH_4)_2S$ ppt Fe^{+3}. 4.) Add Na_3PO_4 or Na_2CO_3 or Na_3SO_3 ppt Be^{+2}.